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VARIATION IN VERTEBRAL NUMBERS OF JUVENILE ATLANTIC MENHADEN

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by

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ABSTRACT

Juvenile Atlantic menhaden *(Brevoortia tyrannus)*, collected in 45 estuaries along the Atlantic coast of the United States, were examined for vertebral numbers. Analysis of variance of mean vertebral numbers of 17,024 fish in 182 samples from 4 successive year classes, 1956-59, indicated that two groups, or subpopulations, of juveniles existed, one north and the other south of Long Island, N.Y. Sex, size, and water temperature were considered in the interpretation of the data.

INTRODUCTION

Adult Atlantic menhaden *(Brevoortia tyrannus)* occur along the Atlantic Coast of the United States from central Maine to central Florida. Larvae enter estuaries soon after the occurrence of eggs in nearby oceanic waters (Herman, 1959; Kuntz and Radcliffe, 1917; Perlmutter, 1939; Reintjes, 1961; Richards, 1959; Wheatland, 1956). Juveniles are found in most estuaries from Cape Cod, Mass., to northern Florida and only occasionally stray beyond these geographic limits (Scattergood, Trefethen, and Coffin, 1951; Springer and Woodburn, 1960). They spend the first summer of life in estuaries, emigrate to sea in the fall, and appear in huge schools off the coast of North Carolina in December and January. In the following summer, they normally are the main support of the commercial purse seine fishery from Delaware to Florida (June, 1961; June and Reintjes, 1959, 1960).

Variations in abundance of juveniles and adults, both within and between years, have led to the question of whether this species is homogeneous through its range, or is composed of groups, each with its own biological characteristics and range. One approach to this problem is the comparison of body structure of juveniles from different estuarine nurseries, since those inhabiting a given estuary are more likely to have originated from a nearby, rather than a distant parent stock. Furthermore, the occurrence of juveniles in a given estuary provides a known starting point in the life cycle.

From an analysis of selected meristic characters, June (1958) found that juveniles of the 1955 year class were separable into two subpopulations, one occurring north and the other south of Long Island, N.Y. The purpose of the present study was to examine 4 successive year classes, 1956-59, to determine if the earlier findings were confirmed or refuted on the basis of vertebral numbers.

MATERIALS AND METHODS

Juveniles, comprising 182 samples of 17,024 fish, were collected, mostly by beach seine, from 45 estuaries along the Atlantic coast from 1956 to 1959. A few collections were

Note.--Doyle F. Sutherland, Fishery Research Biologist, formerly stationed at the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C., at present is stationed at Weiser, Idaho.

obtained from filter screens at electric power plants and by otter trawl and cast net. Fish were preserved in 10 percent formalin at the time of collection, later leached in water, and stored in 40 percent isopropyl alcohol. Locality and date for each collection are shown in appendix tables 1 through 4.

Vertebral counts were made from X-ray photographs of fish (fig. 1) larger than 30 mm. fork length (Sutherland, 1958) and from stained and cleared fish that were less than 30 mm. (Clothier, 1950). Counts included the total segments between, but not including, the occipital bone and the hypurals. Abnormal vertebrae were counted when distinguished by a suture between fused centra or the presence of a neural or hemal spine. Fork length, in millimeters, and sex were determined for each fish.

Vertebral counts were analyzed (Snedecor, 1956) for sample size requirements and variations by sex and length, in the frequency of fused vertebrae, and within and between samples from different localities, geographic groups, and year classes.

RESULTS OF ANALYSES

Sample size

Sample size was maintained at or near 100 specimens where possible as determined from sample variance ($\sigma 2$) in the formula $\frac{4\sigma 2}{L^2}$. Variance of test samples ranged between 0.17 and 0.35. An L-value of 0.10 vertebra, selected as the allowable error with a 5-percent chance that the error of the sample mean would be exceeded, indicated that samples of 68-140 fish were required.

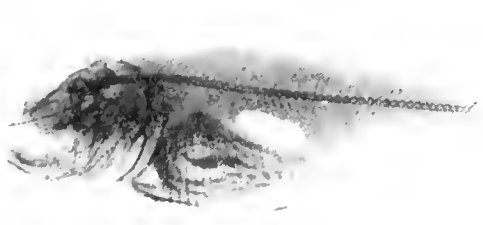

Figure 1.--X-ray photograph of a juvenile Atlantic menhaden.

Vertebral abnormalties

Abnormal vertebrae occurred in 1.4 percent of specimens examined. The most frequent type was the fusion of two centra (53.6 percent). Others included fusion of three or more centra, heavily ossified fused and nonfused centra, and centra with more than one neural or hemal spine. An estimated 0.5 to 1 percent of all specimens examined had curved vertebral columns, but these were not considered an abnormality unless accompanied by one of the previously described types. These abnormalities are similar to those found in young Pacific herring, *Clupea pallasii*, (McHugh, 1942), although they occurred less frequently in Atlantic menhaden than in herring.

Vertebral abnormalities were not randomly distributed. The percentages for all years, by major coastal areas, were 2.8 percent in the North Atlantic (Cape Cod, Mass., to Sandy Hook, N.J.), 1.0 percent in the Middle Atlantic (Sandy Hook, N.J., to Chesapeake Bay), and 1.9 percent in the South Atlantic (Chesapeake Bay to Nassau River, Fla.). Chi-square tests applied to the data for the 1956 and 1957 year classes indicated that the differences were significant ($P < 0.05$) between the North and Middle Atlantic and between the South and Middle Atlantic, but not between the North and South Atlantic. This suggests that a common factor may be responsible for the greater frequency of vertebral abnormalities in the North and South Atlantic areas.

Variation between sexes

Analysis of 1,778 juveniles (table 1) showed that the mean vertebral numbers of males and females differed significantly ($P < 0.05$) in only one of 18 samples. Since the frequency of occurrence was about the same as that expected in random sampling (1 in 20), sexual differences were not considered an important source of variation and were not included in the analysis of the data. The unweighted means of the test samples were 46.95 for males and 46.96 for females.

Variation with length

Regressions of vertebral number on fish length were calculated for the same samples

Table 1.--Mean vertebral numbers of male and female juvenile Atlantic menhaden from different localities, 1956-59

Date and locality	Males			Females		
	Mean	$S(X-X)^2$	Number	Mean	$S(X-X)^2$	Number
1956						
Childs River, Mass.	46.66	14.83	54	46.52	11.98	40
Reeves Bay, N.Y.	47.18	6.55	44	47.14	10.86	56
Indian River, Del.	46.83	4.50	18	47.01	22.99	81
Little River, N.C.	47.12	12.40	42	47.09	14.57	58
St. Catherines Sound, Ga.	47.06	12.81	47	47.13	12.08	53
1957						
Childs River, Mass.	46.79	16.67	52	46.82	12.55	44
Saugatuck River, Conn.	46.50	11.00	44	46.62	14.98	55
Indian River, Del.[1].....	47.15	11.69	62	46.97	6.97	37
Neuse River, N.C.	47.02	10.98	52	46.98	10.98	48
Edisto River, S.C.	46.90	8.50	50	47.00	10.00	48
1958						
Weir Creek, Mass.	46.80	11.60	60	46.76	10.87	38
Ball Creek, Va.	47.05	12.86	65	47.03	4.97	34
Indian Field Creek, Va.	47.07	9.72	58	47.10	13.62	42
Broad Creek, N.C.	47.05	3.90	39	47.10	23.39	59
1959						
Indian River, Del.	47.05	21.79	77	46.86	2.59	22
Ball Creek, Va.	47.03	23.95	75	47.04	4.96	25
Indian Creek, Va.	46.91	21.44	64	47.03	4.97	36
Broad Creek, N.C.	47.00	12.00	55	47.09	9.64	44

[1] P Less than 0.05.

used in analysis of vertebral variation between the sexes. Of the 18 samples tested, 14 positive and 4 negative regression coefficients were obtained, two of which differed significantly from zero (1 of these was positive and significant at the 5-percent level of probability and the other negative and significant at the 1-percent level). These results indicate that fish length may be a source of variation; however, since no consistent pattern was evident, length was not considered in subsequent analyses.

Variation among samples and localities

Vetebral counts of 17,024 juveniles ranged from 44 (1 specimen) to 49 (7 specimens) with the greatest number having 47 vetebrae (12,281). Vertebral counts, by samples, localities, and dates of collection, are given in appendix tables 1 through 4.

The mean numbers of vertebrae in all samples of the 4 year classes were tested for homogeneity by analysis of variance (table 2). Heterogeneity of means within and between localities was indicated by the variance ratios of the 1956 and 1957 year classes. Figure 2 shows that, on the basis of mean vertebral numbers, the fish were separated into two major groups,[1] one extending north of latitude

[1] Marr (1957) defined group as "a fraction of a population with distinctive characteristics, the nature of which (phenotypic or genotypic) has not yet been determined."

Table 2.--Analysis of variance of mean vertebral numbers of juvenile Atlantic menhaden to test for differences within and between localities, 1956-59

Year class	Source variation	Degrees of freedom	Sum of squares	Mean square	F
1956.....	Localities...	34	181.80	5.35	[1] 2.99
	Samples.....	25	44.81	1.79	[1] 6.88
	Individuals..	5,652	1,484.58	0.26	
1957.....	Localities...	33	232.79	7.05	[1] 9.79
	Samples.....	57	41.07	0.72	[1] 2.88
	Individuals..	8,338	2,117.28	0.25	
1958.....	Localities...	5	15.01	3.00	[2] 10.71
	Samples.....	5	1.38	0.28	1.17
	Individuals..	1,080	260.29	0.24	
1959.....	Localities...	7	24.10	3.44	[1] 28.67
	Samples.....	11	1.37	0.12	0.48
	Individuals..	1,773	449.81	0.25	

[1] $P < 0.01$.
[2] $P < 0.05$.

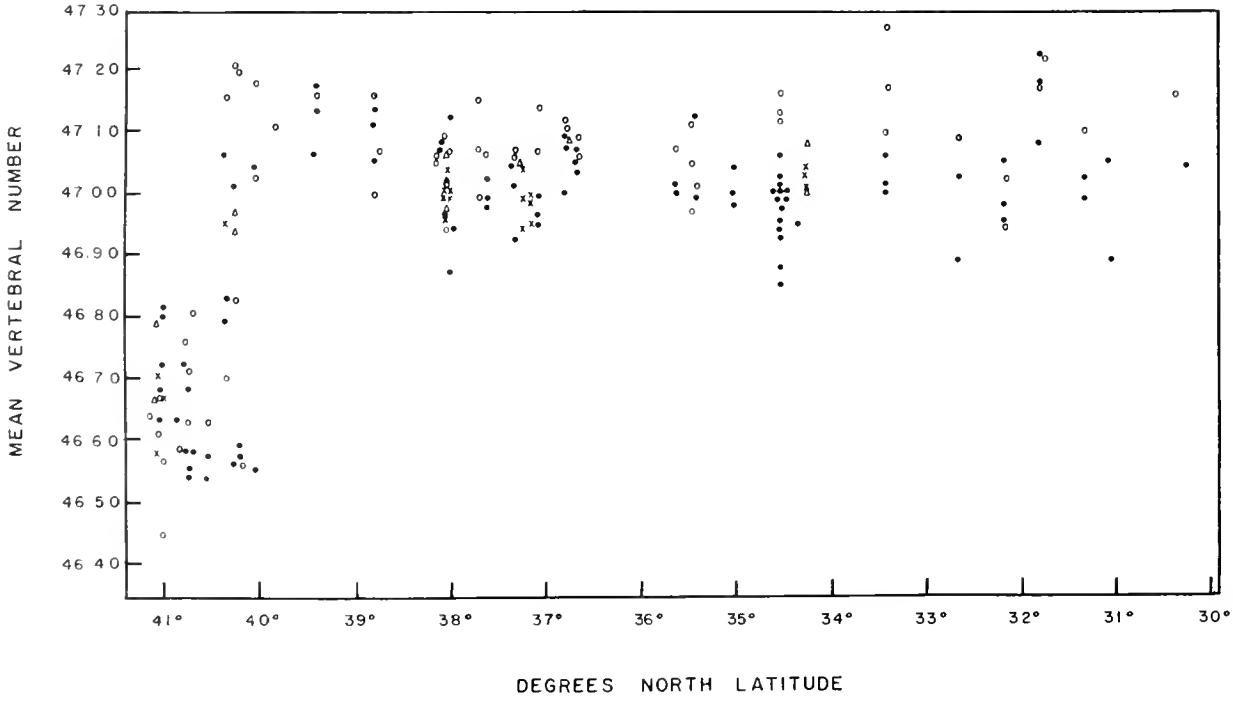

Figure 2.--Distribution of mean vertebral numbers of juvenile Atlantic menhaden, by latitude, 1956-59. (Sample means for fish of the 1956 year class are shown by open circles, 1957 year class by solid dots, 1958 year class by triangles, and 1959 year class by crosses.)

40°35' N. (Hudson River, N. Y.) and the other extending south of latitude 40°56' N. (North Sea Harbor, Long Island, N.Y.). The two groups overlapped in the vicinity of latitudes 40°35' to 40°56' N., but based on differences in sample means, maintained their separate identity. The means of the two groups differed in 1956 by 0.44 vertebra and in 1957 by 0.37 vertebra.

A similar pattern was shown by the means of the 1958 and 1959 year classes, but the means of the two groups differed in 1958 by only 0.29 vertebra and in 1959 by 0.26 vertebra. Heterogeneity of sample means within localities was not indicated for either year class probably because of the paucity of samples from estuaries in the vicinity of latitudes 40°35' to 40°56' N.

Variation within groups

Analysis of variance to determine the variation of means within groups (table 3) showed heterogeneity within the southern group in 1956 and within the northern group in 1957. This heterogeneity does not necessarily indicate the existence of additional groups, but

Table 3.--Analysis of variance of mean vertebral numbers of juvenile Atlantic menhaden to test for homogeneity within groups, 1956-59

Year class and group	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
1956					
Northern.....	Localities....	10	11.39	1.14	2.78
	Samples.....	3	1.24	0.41	1.32
	Individuals...	1,333	406.60	0.30	
Southern.....	Localities....	26	13.81	0.53	1.29
	Samples.....	19	7.83	0.41	[1] 1.64
	Individuals...	4,319	1,077.98	0.25	
1957					
Northern.....	Localities....	10	16.82	1.68	[1] 3.82
	Samples.....	13	5.73	0.44	1.52
	Individuals...	2,148	620.48	0.29	
Southern.....	Localities....	24	17.71	0.74	2.18
	Samples.....	42	14.20	0.34	1.42
	Individuals...	6,190	1,496.80	0.24	
1958					
Northern.....	Samples.....	1	0.66	0.66	2.54
	Individuals...	196	50.61	0.26	
Southern.....	Localities....	4	1.31	0.33	1.83
	Samples.....	4	0.72	0.18	0.75
	Individuals...	884	209.68	0.24	
1959					
Northern.....	Localities....	1	0.03	0.03	0.05
	Samples.....	1	0.57	0.57	1.96
	Individuals...	248	71.29	0.29	
Southern.....	Localities....	5	0.64	0.13	1.62
	Samples.....	10	0.80	0.08	0.32
	Individuals...	1,525	378.52	0.25	

[1] $P < 0.05$.

may be due to variations associated with fish length, sex, or simply to chance.

Variation between year classes

The mean vertebral counts of samples within each major group were further tested for homogeneity between years by analysis of variance, using coded values (table 4). Only the means of the southern group differed significantly between year classes. The unweighted means of individual year classes were as follows: 1956--47.09; 1957--47.02; 1958--47.02; and 1959--47.00. The heterogeneity within the southern group may be attributed to the slightly greater mean of the 1956 year class, for analysis indicated that the means of the other year classes were homogeneous.

DISCUSSION

The number of meristic parts in fishes is known to vary with temperature (Jordan, 1892; McHugh, 1951; Seymour, 1959; Tester, 1938), and variations in vertebral numbers of Atlantic menhaden might be explained on the basis of temperature at the time of spawning. In the North Atlantic area, eggs and larvae have been collected from May to October; from June to October in Long Island Sound (Perlmutter, 1939; Wheatland, 1956), and from May to October in Narragansett Bay (Herman, 1959). Fish in near-spawning condition are caught by gill nets as early as March in the vicinity of Point Judith, R.I. Pound net catches in Raritan and Lower New York Bays include some near-ripe fish in March and April (Higham and Nicholson, unpublished MS.[2]) Thus, it is likely that some spawning takes place in northern waters from April to October. Based on the occurrence of near-ripe fish in purse seine catches and the occurrence of eggs and larvae, spawning in the Middle and South Atlantic areas appears to take place from October to April, although it may begin in September and continue through May. Larvae apparently enter estuaries soon after hatching (June and Chamberlin, 1959; McHugh, Oglesby, and Pacheco, 1959; Perlmutter, 1939).

Mean monthly surface water temperatures at nine locations along the Atlantic coast where spawning is presumed to occur are shown in figure 3 (Bumpus, 1957; Day, 1959a, 1959b, 1960). The figure shows a sharp increase in the mean April to October temperatures sough of Ambrose Lightship to approximately Chesapeake Bay. Mean temperatures south of Chesapeake Bay exceed those north of Ambrose Lightship during the spawning period and vary from approximately 45° F. in January to approximately 70° F. in May.

Although there may be some selection by spawning fish of a temperature stratum entirely different from that shown in the graph, it would appear from these data that the variation in mean vertebral numbers of juvenile Atlantic menhaden may be associated with water temperature at spawning time. There is relative stability in vertebral numbers in 5 successive year classes despite wide variations in temperature within and between years

[2] Sexual maturation and spawning of Atlantic menhaden. Unpublished manuscript, Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C.

Table 4.--Analysis of variance of mean vertebral numbers of juvenile Atlantic menhaden to test for differences between year classes within groups, 1956-59

Group	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Northern.....	Years.....	3	125.87	41.96	
	Means.....	39	3,924.60	100.63	0.42
Southern.....	Years.....	3	1,828.90	609.63	
	Means.....	134	6,065.57	45.26	[1] 13.47

[1] $P < 0.01$.

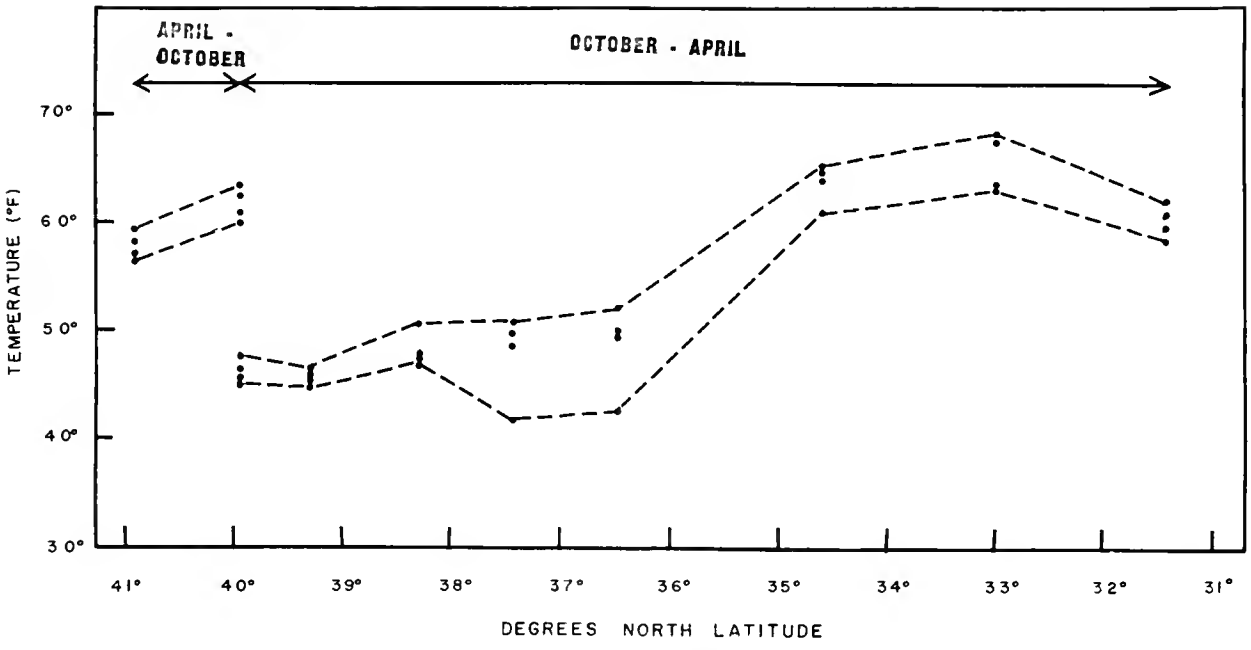

Figure 3.--Distribution of mean seasonal water temperatures along the Atlantic coast of the United States, by latitude.

and with separate spawning times. Furthermore the occurrence of two groups of juveniles within the same estuaries in Long Island which could be separated by mean vertebral numbers and identified with either the northern or southern subpopulations suggest genetic origin. A followup study of these same year classes at the time the fish reach sexual maturity should determine whether or not the pattern in vertebral numbers is similar to that exhibited when they were juveniles in adjacent estuarine nurseries.

SUMMARY

1. Collections of juvenile Atlantic menhaden *(Brevoortia tyrannus)*, comprising 182 samples and 17,024 fish, were made in selected estuaries from Cape Cod, Mass. to northern Florida during 4 successive years, 1956-59.

2. Vertebral counts were made from X-ray photographs and stained specimens.

3. Preliminary analyses determined the sample size requirements, and variation with sex and fish length. Significant variation with sex occurred in only 1 of 18 samples tested and was disregarded in subsequent analyses. Positive and negative regressions of vertebral number on fish length were obtained, but the coefficients differed significantly from zero in only two of 18 samples tested. Length was disregarded as a source of variation in subsequent analyses.

4. Analysis of variance was used to examine variation within and between samples, localities, groups, and year classes. There was less variation within and between samples from a given locality and within a geographic group than between two geographic groups. It was concluded that, except for the 1956 year class in the southern group, variation between year classes was not significant.

5. The hypothesis that at least two groups, or subpopulations, of juvenile Atlantic menhaden exist was supported by statistical analysis of variation in vertebral numbers.

6. Variation in vertebral number was associated with water temperature differences during the spawning seasons.

LITERATURE CITED

BUMPUS, D. F.
1957. Oceanographic observations, 1956, east coast of the United States. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 233, 132 p.

CLOTHIER, CHARLES R.
1950. A key to some southern California fishes based on vertebral characters. California Division of Fish and Game, Fish Bulletin No. 79, 83 p.

DAY, C. GODFREY.
1959a. Oceanographic observations, 1957, east coast of the United States. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 282, 123 p.

1959b. Oceanographic observations, 1958, east coast of the United States. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 318, 119 p.

1960. Oceanographic observations, 1959, east coast of the United States. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 359, 114 p.

HERMAN, SIDNEY S.
1959. The planktonic fish eggs and larvae of Narragansett Bay. Appendix I. U.S. Fish and Wildlife Service, Sustaining data summary on fishery resources in relation to the hurricane damage control program for Narragansett Bay and vicinity Rhode Island and Massachusetts (May 1959) Boston, Mass., 24 p. (Processed report.)

JORDAN, DAVID STARR.
1892. Relations of temperature to vertebrae among fishes. Proceedings of the U.S. National Museum, vol. 14, p. 107-120.

JUNE, FRED C.
1958. Variation in meristic characters of young Atlantic menhaden, *Brevoortia tyrannus*. Rapport et Proces-Verbaux des Réunions, Counseil Permanent International pour l'Exploration de la Mer, vol. 143, part 2, no. 4, p. 26-35.

1961. Age and size composition of the menhaden catch along the Atlantic Coast of the United States, 1957; with a brief review of the commercial fishery. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 373, 39 p.

JUNE, FRED C., and J. LOCKWOOD CHAMBERLIN.
1959. The role of the estuary in the life history and biology of Atlantic menhaden. Proceedings of the Gulf and Caribbean Fisheries Institute, Eleventh Annual Session (1958), p. 41-45.

JUNE, FRED C., and JOHN W. REINTJES.
1959. Age and size composition of the menhaden catch along the Atlantic Coast of the United States, 1952-55; with a brief review of the commercial fishery. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 317, 65 p.

1960. Age and size composition of the menhaden catch along the Atlantic Coast of the United States, 1956; with a brief review of the commercial fishery. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 336, 38 p.

KUNTZ, ALBERT, AND LEWIS RADCLIFFE.
1917. Notes on the embryology and larval development of twelve teleostean fishes. Bulletin of the U.S. Bureau of Fisheries, vol. 35, for 1915-16, p. 87-134.

MARR, JOHN C.
1957. The problem of defining and recognizing subpopulations of fishes. In Contributions to the study of subpopulations of fishes, U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 208, p. 1-7.

McHUGH, J. L.
1942. Variation of vertebral centra in young Pacific herring *(Clupea pallasii)*. Journal of the Fisheries Research Board of Canada, vol. 5, no. 4, p. 347-360.

McHUGH, J. L.
1951. Meristic variations and populations of northern anchovy *(Engraulis mordax mordax).* Bulletin of the Scripps Institution of Oceanography, technical series, vol. 6, no. 3, p. 123-160.

McHUGH, J. L., R. T. OGLESBY, and A. L. PACHECO.
1959. Length, weight, and age composition of the menhaden catch in Virginia waters. Limnology and Oceanography, vol. 4, no. 2, p. 145-162.

PERLMUTTER, ALFRED.
1939. An ecological survey of young fish and eggs identified from two-net collections. In A biological survey of the salt waters of Long Island, 1939, part 2, p. 11-71. New York Conservation Department.

REINTJES, JOHN W.
1961. Menhaden eggs and larvae from M/V *Theodore N. Gill* cruises, South Atlantic Coast of the United States, 1953-54. U.S. Fish and Wildlife Services, Special Scientific Report--Fisheries No. 393, 7 p.

RICHARDS, SARAH W.
1959. Pelagic fish eggs and larvae of Long Island Sound. In Oceanography of Long Island Sound. Bulletin of the Bingham Oceanographic Collection, vol. 17, art. 1, p. 95-124.

SCATTERGOOD, LESLIE W., PARKER S. TREFETHEN, AND GARETH W. COFFIN.
1951. Notes on the size of menhaden taken in Maine during 1949. Copeia, 1951, no. 1 (March), p. 93-94.

SEYMOUR, ALLYN.
1959. Effects of temperature upon the formation of vertebrae and fin rays in young chinook salmon. Transactions of the American Fisheries Society, vol. 88, no. 1, p. 58-69.

SNEDECOR, GEORGE W.
1956. Statistical methods. Iowa State College Press, Ames, Iowa, 5th edition, 534 p.

SPRINGER, VICTOR G., and KENNETH D. WOODBURN.
1960. An ecological study of the fishes of the Tampa Bay area. Professional Papers Series of the Florida State Board of Conservation Marine Laboratory, no. 1, 104 p.

SUTHERLAND, DOYLE F.
1958. Use of diagnostic X-ray for determining vertebral numbers of fish. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 244, 9 p.

TESTER, ALBERT L.
1938. Variation in the mean vertebral count of herring *(Clupea pallasii)* with water temperature. Journal du Conseil, Permanent International Pour l'Exploration de la Mer, vol. 13, no. 1, p. 71-75.

WHEATLAND, SARAH B.
1956. Pelagic fish eggs and larvae. In Oceanography of Long Island Sound, 1952-54. Bulletin of the Bingham Oceanographic Collection, vol. 15, p. 234-314.

APPENDIX

Appendix Table 1.--Vertebral number of juvenile Atlantic menhaden in samples from different localities, 1956

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Childs River, Mass.:								
Sept. 3	6	45	39	5	---	95	46.45	---
Oct. 13	1	39	53	1	---	94	46.57	---
Locality total	7	84	92	6	---	189	---	46.51
Acushnet River, Mass.:								
Sept. 12	1	41	54	2	1	99	46.61	---
Oct. 13	---	34	57	3	---	94	46.67	---
Locality total	1	75	111	5	1	193	---	46.64
Taunton River, Mass.:								
Nov. 26-Dec. 29	1	31	52	2	---	86	46.64	46.64
Poguonuck River, Conn.:								
Sept. 11	1	25	71	3	---	100	46.76	46.76
Thames River, Conn.:								
Oct. 15	---	39	50	2	---	91	46.59	46.59
Connecticut River, Conn.:								
Sept. 11	---	32	65	3	---	100	46.71	---
Oct. 12	1	38	57	3	---	99	46.63	---
Locality total	1	70	122	6	---	199	---	46.67
Hammonasset River, Conn.:								
Sept. 10	---	28	63	9	---	100	46.81	46.81
Saugatuck River, Conn.:								
Oct. 11	---	39	58	2	---	99	46.63	46.63
Reeves Bay, N. Y.:								
Aug. 2	---	2	80	18	---	100	[1] 47.16	---
Oct. 10	1	30	63	3	---	97	[2] 46.70	---
Locality total	1	32	143	21	---	197	---	46.93
Quantuck Creek, N.Y.:								
Aug. 3	---	7	63	28	---	98	[1] 47.21	---
Oct. 9	---	19	73	3	---	95	[2] 46.83	---
Locality total	---	26	136	31	---	193	---	47.02
Carmans River, N. Y.:								
Aug. 3	---	2	76	22	---	100	[1] 47.20	---
Oct. 8	1	39	57	1	---	98	[2] 46.56	---
Locality total	1	41	133	23	---	198	---	46.90

See footnotes at the end of the table.

Appendix Table 1.--Vertebral number of juvenile Atlantic menhaden in samples from different localities, 1956 (continued)

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Hudson River, N.Y.:								
July 31	---	10	75	13	---	98	[1] 47.03	---
Oct. 7	---	5	60	20	---	85	[1] 47.18	---
Locality total	---	15	135	33	---	183	---	47.10
Navesink River, N.J.:								
July 8	---	5	77	16	---	98	47.11	47.11
Toms River, N.J.:								
July 30	---	4	76	20	---	100	47.16	47.16
Great Egg River, N.J.:								
July 30	1	10	76	12	---	99	47.00	---
Oct. 6	---	7	70	22	1	100	47.16	---
Locality total	1	17	146	34	1	199	---	47.08
Indian River, Del.:								
Aug. 31	---	8	80	11	---	99	47.03	---
Sept. 14	---	12	73	15	---	100	47.03	---
Locality total	---	20	153	26	---	199	---	47.03
White Creek, Del.:								
Aug. 16	---	9	73	18	---	100	47.09	---
Aug. 23	---	14	75	8	---	97	46.94	---
Sept. 14	---	15	71	13	---	99	47.01	---
Locality total	---	38	219	39	---	296	---	47.01
Chester River, Md.:								
Aug. 3	---	6	64	5	---	75	46.99	---
Aug. 8	---	6	81	13	---	100	47.07	---
Oct. 4	---	6	72	21	---	99	47.15	---
Locality total	---	18	217	39	---	274	---	47.01
Choptank River, Md.:								
Aug. 15	---	11	72	16	---	99	47.05	---
Oct. 4	---	9	76	15	---	100	47.06	---
Locality total	---	20	148	31	---	199	---	47.06
Patuxent River, Md.:								
July 28	---	9	76	14	1	100	47.07	47.07
Potomac River, Md.:								
July 28	---	11	72	17	---	100	47.06	47.06
Great Wicomico River, Va.:								
Aug. 6	---	8	78	14	---	100	47.06	---
Sept. 25	---	7	78	13	---	98	47.06	---
Locality Total	---	15	156	27	---	198	---	47.06

See footnotes at the end of the table.

Appendix Table 1.--Vertebral number of juvenile Atlantic menhaden in samples from different localities, 1956 (continued)

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Rappahannock River, Va.:								
July 27	---	5	75	19	---	99	47.14	---
Sept. 25	---	7	79	14	---	100	47.07	---
Locality total	---	12	154	33	---	199	---	47.10
York River, Va.:								
July 27	---	9	72	19	---	100	47.10	---
Sept. 24	---	9	71	20	---	100	47.11	---
Locality total	---	18	143	39	---	200	---	47.10
James River, Va.:								
July 26	---	14	66	20	---	100	47.06	---
Sept. 24	---	8	75	17	---	100	47.09	---
Locality total	---	22	141	37	---	200	---	47.08
Chowan River, N.C.:								
Aug. 7	---	9	73	16	---	98	47.07	47.07
Albemarle Sound, N.C.:								
June 20	---	10	69	21	---	100	47.11	---
June 29	---	16	65	13	---	94	46.97	---
July 10	1	6	72	13	---	92	47.05	---
Locality total	1	32	206	47	---	286	---	47.04
Roanoke River, N.C.:								
July 10	---	9	65	10	---	84	47.01	47.01
Neuse River, N.C.:								
May 23	---	8	69	20	---	97	47.12	---
June 1	---	7	74	18	1	100	47.13	---
Oct. 2	---	3	32	10	---	45	47.16	---
Locality total	---	18	175	48	1	242	---	47.14
Little River, N.C.:								
July 21	---	5	62	32	---	99	47.27	---
Aug. 20	---	4	74	21	---	99	47.17	---
Nov. 1	---	9	72	19	---	100	47.10	---
Locality total	---	18	208	72	---	298	---	47.18
Jeremy Creek, S.C.:								
Aug. 21	---	8	75	17	---	100	47.09	47.09
Edisto River, S.C.:								
July 18	---	8	34	5	---	47	46.94	---
Aug. 22	1	9	76	13	---	99	47.02	---
Locality total	1	17	110	18	---	146	---	46.98

See footnotes at the end of the table.

Appendix Table 1.--Vertebral number of juvenile Atlantic menhaden in samples from different localities, 1956 (continued)

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Mays River, S.C.:								
Aug. 9.....	---	2	78	19	---	99	47.17	47.17
St. Catherines Sound, Ga.:								
Aug. 24.....	---	8	74	18	---	100	47.10	47.10
St. Marys River, Ga.:								
July 12.....	---	3	52	14	---	69	47.16	47.16
Grand total.....	16	838	4,060	794	4	5,712	---	---

[1] Sample identified with southern group.
[2] Sample identified with northern group.

Appendix Table 2.--Vertebral numbers of juvenile Atlantic menhaden in samples from different localities, 1957

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Childs River, Mass.:								
Aug. 30	1	31	63	2	---	97	46.68	---
Sept. 2	---	20	78	1	---	99	46.81	---
Sept. 13	1	23	66	6	---	96	46.80	---
Locality total	2	74	207	9	---	292	---	46.76
Acushnet River, Mass.:								
Sept. 2	---	35	61	2	---	98	46.66	46.66
Wickford Harbor, R.I.:								
Aug. 29	---	32	61	5	---	98	46.72	---
Sept. 2	---	40	54	4	---	98	46.63	---
Sept. 9	---	14	45	1	---	60	46.78	---
Locality total	---	86	160	10	---	256	---	46.71
Thames River, Conn.:								
Aug. 29	---	30	47	1	---	78	46.63	46.63
Connecticut River, Conn.:								
Aug. 29	---	20	40	2	---	62	46.71	---
Sept. 3	---	42	57	---	---	99	46.58	---
Sept. 12	---	33	63	2	---	98	46.68	---
Locality total	---	95	160	4	---	259	---	46.66
Hammonasset River, Conn.:								
Aug. 29	2	39	57	1	---	99	46.58	---
Sept. 3	3	38	57	---	---	98	46.55	---
Sept. 12	1	46	51	2	---	100	46.54	---
Locality total	6	123	165	3	---	297	---	46.56
Saugatuck River, Conn.:								
Sept. 3	2	44	48	3	---	97	46.54	---
Sept. 11	1	41	57	---	---	99	46.57	---
Locality total	3	85	105	3	---	196	---	46.56
Skilmans Creek, N.Y.:								
Aug. 10	---	10	74	16	---	100	[1] 47.06	47.06
Reeves Bay, N.Y.:								
July 13	---	20	77	3	---	100	[2] 46.83	---
Sept. 4	1	25	68	6	---	100	[2] 46.70	---
Sept. 4	1	20	34	3	1	59	[2] 46.71	---
Locality total	2	65	179	12	1	259	---	46.78

See footnotes at the end of the table.

Appendix Table 2.--Vertebral numbers of juvenile Atlantic menhaden in samples from different localities, 1957 (continued)

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Quantuck Creek, N.Y.:								
July 14	---	15	69	16	---	100	[1] 47.01	---
Aug. 10	1	42	48	3	---	94	[2] 46.56	---
Sept. 4	---	53	46	1	---	100	[2] 46.48	---
Locality total	1	110	163	20	---	294	---	46.68
Carmans River, N.Y.:								
Aug. 9	1	39	52	2	---	94	[2] 46.59	---
Sept. 4	1	41	52	2	---	96	[2] 46.57	---
Locality total	2	80	104	4	---	190	---	46.58
Hudson River, N.Y.:								
Aug. 8 - 9	1	11	72	16	---	100	[1] 47.03	---
Aug. 27	2	20	31	---	---	33	[2] 46.55	---
Locality total	3	31	103	16	---	153	---	46.79
Toms River, N.J.:								
July 11	---	5	73	22	---	100	47.17	---
Aug. 8	---	4	76	17	---	97	47.13	---
Sept. 5	---	6	65	11	---	82	47.06	---
Locality total	---	15	214	50	---	279	---	47.12
Great Egg River, N.J.:								
July 10	---	7	52	15	---	74	47.11	---
Aug. 7	---	12	71	17	---	100	47.05	---
Sept. 5	---	4	79	17	---	100	47.13	---
Locality total	---	23	202	49	---	274	---	47.10
White Creek, Del.:								
July 18	---	10	82	7	---	99	46.97	---
July 26	---	10	75	12	---	97	47.02	---
Aug. 22	---	6	79	14	---	99	47.08	---
Locality total	---	26	236	33	---	295	---	47.02
Patuxent River, Md.:								
July 10	---	4	74	15	---	93	47.12	---
Aug. 7	1	16	78	5	---	100	46.87	---
Sept. 14	---	15	76	9	---	100	46.94	---
Locality total	1	35	228	29	---	293	---	46.98

See footnotes at the end of the table.

Appendix Table 2.--Vertebral numbers of juvenile Atlantic menhaden in samples from different localities, 1957 (continued)

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Potomac River, Va.:								
July 9	---	10	82	8	---	100	46.98	---
Aug. 6	---	13	74	11	---	98	46.98	---
Sept. 15	---	12	74	14	---	100	47.02	---
Locality total	---	35	230	33	---	298	---	46.99
Great Wicomico River, Va.:								
July 9	---	16	76	8	---	100	46.92	---
Aug. 6	---	10	80	9	1	100	47.01	---
Sept. 15	---	8	58	12	---	78	47.05	---
Locality total	---	34	214	29	1	278	---	46.99
Rappahannock River, Va.:								
July 9	---	12	80	8	---	100	46.96	---
Aug. 6	---	17	71	12	---	100	46.95	---
Sept. 15	---	10	80	9	---	99	46.99	---
Locality total	---	39	231	29	---	299	---	46.97
York River, Va.:								
July 8	---	13	74	13	---	100	47.00	---
Aug. 6	---	6	78	16	---	100	47.10	---
Sept. 15	---	9	73	17	---	99	47.08	---
Locality total	---	28	225	46	---	299	---	47.06
James River, Va.:								
July 8	---	10	74	15	---	99	47.05	---
Aug. 5	---	11	75	14	---	100	47.03	---
Sept. 16	---	11	57	17	---	85	47.07	---
Locality total	---	32	206	46	---	284	---	47.05
Chowan River, N.C.:								
July 3	---	12	73	12	---	97	47.00	---
July 31	---	11	76	11	---	98	47.00	---
Locality total	---	23	149	23	---	195	---	47.00
Scuppernong River, N.C.:								
July 2	---	10	65	22	---	97	47.12	---
July 31	---	15	71	14	---	100	46.99	---
Locality total	---	25	136	36	---	197	---	47.06

See footnotes at the end of the table.

Appendix Table 2.--Vertebral numbers of juvenile Atlantic menhaden in samples from different localities, 1957 (continued)

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Pamlico River, N.C.:								
July 2	---	13	70	17	---	100	47.04	---
July 31	1	8	72	10	---	91	47.00	---
Sept. 19	---	13	76	11	---	100	46.98	---
Locality total	1	34	218	38	---	291	--	47.01
Neuse River, N.C. (Upper):								
May 27	1	11	81	7	---	100	46.94	---
May 27	---	10	73	16	---	99	47.06	---
June 4	---	13	70	13	---	96	47.00	---
July 17	---	12	76	11	---	99	46.99	---
Sept. 18	---	9	80	11	---	100	47.02	---
Sept. 19	---	17	71	12	---	100	46.95	---
Locality total	1	72	451	70	---	594	---	46.99
Neuse River, N.C. (Lower):								
June 4	1	17	75	7	---	100	46.88	---
July 5	---	12	75	13	---	100	47.01	---
July 17	---	9	82	8	---	99	46.99	---
Sept. 18	---	11	78	11	---	100	47.00	---
Locality total	1	49	310	39	---	399	---	47.00
Adams Creek, N.C.:								
June 4	---	16	75	9	---	100	46.93	---
July 17	---	12	79	9	---	100	46.97	---
Sept. 18	1	20	72	7	---	100	46.85	---
Oct. 1	---	6	39	6	---	51	47.00	---
Locality total	1	54	265	31	---	351	---	46.94
Little River, N.C.:								
June 23	1	4	83	12	---	100	47.06	---
July 22	---	18	64	18	---	100	47.00	---
Oct. 23	---	9	76	10	---	95	47.01	---
Locality total	1	31	223	40	---	295	---	47.04
Jeremy Creek, S.C.:								
July 22	---	3	55	4	---	62	47.02	---
Sept. 30	---	23	65	12	---	100	46.89	---
Locality total	---	26	120	16	---	162	---	46.95

See footnotes at the end of the table.

Appendix Table 2.--Vertebral numbers of juvenile Atlantic menhaden in samples from different localities, 1957 (continued)

Locality and date	Number of fish with counts of--					Total	Mean	
	45	46	47	48	49		Sample	Locality
Edisto River, S.C.:								
June 24	---	5	84	10	---	99	47.05	---
July 23	---	14	74	12	---	100	46.98	---
Oct. 1	1	9	82	6	---	98	46.95	---
Locality total	1	28	240	28	---	297	---	46.99
Mays River, S.C.:								
June 25	---	4	69	26	---	99	47.22	---
July 14-24	---	5	35	14	---	54	47.17	---
Sept. 19	---	7	40	12	---	59	47.08	---
Locality total	---	16	144	52	---	212	---	47.16
St. Catherines Sound, Ga.:								
June 25	---	8	82	10	---	100	47.02	---
July 24	---	7	61	6	---	74	46.99	---
Locality total	---	15	143	16	---	174	---	47.01
Sapelo Marsh, Ga.								
June 26	---	10	50	3	---	63	46.89	---
July 25	---	3	46	6	---	55	47.05	---
Locality total	---	13	96	9	---	118	---	46.97
Nassau River, Fla.:								
June 27	---	6	58	9	---	73	47.04	47.04
Grand total	26	1,483	6,067	851	2	8,429	---	---

[1] Sample identified with southern group.
[2] Sample identified with northern group.

Appendix Table 3.--Vertebral numbers of juvenile Atlantic menhaden in samples from different localities, 1958

Locality and date	Number of fish with counts of--				Total	Mean	
	45	46	47	48		Sample	Locality
Weir Creek, Mass.:							
Sept. 29	1	33	64	2	100	46.67	---
Sept. 29	---	24	71	3	98	46.79	---
Locality total	1	57	135	5	198	---	46.73
Pennimans Cove, N.Y.:							
Aug. 23	---	15	73	12	100	46.97	---
Aug. 23	---	15	76	9	100	46.94	---
Locality total	---	30	149	21	200	---	46.96
White Creek, Del.							
July 7	---	5	82	11	98	47.06	---
July 16	---	14	73	12	99	46.98	---
July 30	---	11	76	12	99	47.01	---
Locality total	---	30	231	35	296	---	47.02
Ball Creek, Va.							
July 27	---	7	81	11	99	47.04	47.04
Indian Field Creek, Va.:							
Aug. 8	---	8	76	16	100	47.08	47.08
Broad Creek, N.C.							
July 19	1	7	73	17	98	47.08	---
July 20	---	13	74	13	100	47.00	---
Locality total	1	20	147	30	198	---	47.04
Grand total	2	152	819	118	1,091	---	---

Appendix Table 4.--Vertebral numbers of juvenile menhaden in samples from different localities, 1959

Locality and date	Number of fish with counts of--						Total	Mean	
	44	45	46	47	48	49		Sample	Locality
Weir Creek, Mass.:									
Sept. 30	---	2	24	65	1	---	92	46.71	---
Sept. 30	---	1	25	39	---	---	65	46.58	---
Locality total	---	3	49	104	1	---	157	---	46.58
Childs Creek, Mass.:									
Oct. 1	---	---	34	56	4	---	94	46.68	46.68
Herring Creek, N. Y.:									
Aug. 23	---	---	18	69	13	---	100	46.95	46.95
Indian River, Del.:									
July 23	---	---	12	74	13	---	99	47.01	---
July 27	---	---	17	71	11	1	100	46.96	---
July 29	---	---	13	74	13	---	100	47.00	---
Locality total	---	---	42	219	37	1	299	---	46.99
White Creek, Del.:									
May 21	---	---	7	81	7	---	95	47.00	---
June 22	---	---	12	75	12	---	99	47.00	---
Sept. 14	---	---	5	38	7	---	50	47.04	---
Locality total	---	---	24	194	26	---	244	---	47.01
Ball Creek, Va.:									
Aug. 1	---	---	11	78	10	---	99	46.99	---
Aug. 1	---	---	14	78	8	---	100	46.94	---
Aug. 1	---	---	13	71	16	---	100	47.03	---
Locality total	---	---	38	227	34	---	299	---	46.99
Indian Creek, Va.:									
Aug. 14	---	---	16	73	11	---	100	46.95	---
Aug. 14	---	---	12	76	12	---	100	47.00	---
Aug. 14	---	---	10	81	9	---	100	46.99	---
Locality total	---	---	38	230	32	---	300	---	46.98
Broad Creek, N.C.:									
Sept. 8	---	---	9	77	13	---	99	47.04	---
Sept. 8	1	1	8	76	14	---	100	47.01	---
Sept. 8	---	---	7	83	10	---	100	47.03	---
Locality total	1	1	24	236	37	---	299	---	47.03
Grand total	1	4	267	1,335	184	1	1,792	---	---

MS #1202

GPO 933220

Created in 1849, the Department of the Interior—America's Department of Natural Resources—is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

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